

EXECUTIVE SUMMARY

DCERP Annual Technical Report II:
March 2008–February 2009
Executive Summary

SERDP Project RC-1413

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DCERP Annual Technical Report II: March 2008–February 2009

Executive Summary

Overview

The Defense Coastal/Estuarine Research Program (DCERP) is a research-based program sited at Marine Corps Base Camp Lejeune (MCBCL) in North Carolina. This program provides a unique opportunity to integrate the results of broadly scoped ecological research to understand the structure and function of diverse coastal ecosystems, while directly integrating this research to address the Base's management needs for sustaining the military training mission. Phase I of DCERP was successfully completed in June 2007 and resulted in the development of a *DCERP Strategic Plan*, a *Baseline Monitoring Plan*, and a *Research Plan*, which serve as the foundation for the future DCERP activities at MCBCL.

Implementation of these plans (Phase II) was initiated in July 2007 and has resulted in the establishment of more than 300 monitoring and research sites and 13 research projects. In addition, the Data Information and Management System (DIMS) was designed and is now used to archive DCERP monitoring and research data and to allow for the exchange of information among the various DCERP partners. Research and monitoring activities during Phase II of DCERP are currently planned for 4 years (until November 2011) in support of the minimum 10-year vision for the program. This Executive Summary highlights the accomplishments from Phase II (inclusive of March 2008–February 2009).

Major Highlights and Accomplishments from DCERP in 2008

Key findings/outcomes to date with implications for Base management

- Water-level sensors showed that tides at Wallace Creek lag behind Mile Hammock Bay tides by approximately 3.5 hours. The Base can use this information to improve scheduling of amphibious maneuvers in the NRE.
- Preliminary analysis of MCBCL air quality data indicated an increasing trend in ozone and particulate matter concentrations with increasing distance from the ocean; however, none of the data collected from July–December 2008 at the three MCBCL sites exceeded current National Ambient Air Quality Standards.
- Experimental results show that salt marshes bordering the Intracoastal Waterway (ICW) are nutrient limited and show increased growth following fertilization, suggesting that fertilization could be a viable management tool to mitigate the effects of erosion and sea-level rise.
- A zone of maximum phytoplankton productivity was identified in the upper estuary where the New River Estuary (NRE) widens and flow slows, creating an area conducive to bloom development. This area warrants attention by Base watershed managers to reduce nutrient inputs, primarily of nitrogen, identified as the limiting nutrient in the estuary through implementation of both point and nonpoint source controls.

Program products transferred for immediate Base use

- Land Use/Land Cover change analysis data were used by the Base to prepare the Environmental Impact Statement for the 202k "Grow the Force" campaign, which will increase the number of Marines at MCBCL by 8,000.
- Shorebird survey data collected by DCERP researchers were provided to MCBCL for use in the Base's report to the North Carolina Wildlife Resources Commission and for developing an environmental assessment of the potential effects of training activities on Onslow Beach.
- The entire NRE and ICW shorelines were digitized using historic and current aerial photography to provide accurate geographic information systems (GIS) data layers for Base use. These data will be used further by the Coastal Wetlands Module to calculate historic and forecast future shoreline erosion rates.

Key DCERP accomplishments at the programmatic level

- All baseline monitoring stations were established across MCBCL, and data collection activities were ongoing throughout 2008.
- All research projects were up and running by the end of 2008, with the exception of the two Coastal Barrier Module projects and the field component of one Atmospheric Module project, which are scheduled to begin in July 2009.
- The new Monitoring and Research Data Information System (MARDIS) database and Web site were successfully deployed in October 2008, and more than 4 million records of monitoring data are currently available for downloading.

ES-1. Background

Critical military training and testing on lands along the nation's coastal and estuarine shorelines are increasingly placed at risk because of development pressures in surrounding areas, impairments due to other anthropogenic disturbances, and increased requirements for compliance with state and federal environmental regulations. The U.S. Department of Defense (DoD) intends to enhance and sustain its training and testing assets and optimize its stewardship of natural resources through the development and application of an ecosystem-based management approach on DoD facilities.

To assist in this goal, the Strategic Environmental Research and Development Program (SERDP) launched DCERP at MCBCL in North Carolina. MCBCL provides an ideal platform for DCERP because it integrates aquatic/estuarine, coastal wetlands, coastal barrier, and terrestrial ecosystems. DCERP is a collaborative effort among SERDP, the Naval Facilities Engineering Command/Engineering Service Center, MCBCL, and the RTI International¹ (RTI) DCERP Team.

RTI DCERP Team

RTI has assembled a diverse team of experts from the following organizations, collectively referred to as the RTI DCERP Team:

- Atmospheric Research and Analysis
- Duke University
- National Oceanic and Atmospheric Administration
- North Carolina State University
- Porter Scientific
- RTI International
- U.S. Army Corps of Engineers
- U.S. Geological Survey
- University of North Carolina at Chapel Hill
- University of North Carolina at Wilmington
- University of South Carolina
- Virginia Institute of Marine Sciences
- Virginia Polytechnic Institute and State University

ES-2. Integration with MCBCL's Natural Resources Management

As a military installation, MCBCL has needs, or drivers, that must be satisfied to meet its readiness mission without significant disruption. These installation-specific drivers are defined by the Base's mission and geographic location, land uses to support the mission, and natural resources affected by and needed to support the mission (**Table ES-1**). MCBCL must also comply with relevant environmental laws and regulations, such as the federal Endangered Species Act (ESA), Clean Water Act (CWA), and Clean Air Act (CAA), to ensure continuance of its mission. To ensure such compliance, MCBCL developed and adopted an *Integrated Natural Resources Management Plan* (INRMP). One goal of the INRMP is to minimize future training restrictions (i.e., no net loss in the ability to train) by increasing the integration between MCBCL natural resources management planning and military training and operations. One of DCERP's objectives is to assist MCBCL in achieving this goal by providing science-based understanding and tools to assist management. Base staff members were involved throughout the DCERP planning phase by participating in all planning workshops and reviewing the *DCERP Strategic Plan*, *Baseline Monitoring Plan*, and *Research Plan*. A DCERP On-site Coordinator serves as a liaison between the Base, RTI DCERP Team, and SERDP and coordinates and facilitates access to MCBCL lands, facilities, and Base database files by the RTI DCERP Team.

Table ES-1. MCBCL-Specific Military Drivers

Driver 1	Preserving the integrity of the amphibious maneuver areas, including Onslow Bay, the New River Estuary (NRE), and the adjoining training areas and airspace of the Marine Corps Base Camp Lejeune (MCBCL)
Driver 2	Preserving the integrity of MCBCL as a combined-arms training Base by ensuring the continued viability of its impact areas and associated training ranges
Driver 3	Enhancing future training uses of MCBCL ranges, training areas, and airspace by fully integrating the <i>Land Use Master Plan</i> and <i>Range Transformation Plan</i>

¹ RTI International is a trade name of Research Triangle Institute.

Driver 4	Ensuring that MCBCL supports all required military training activities, while complying with the Endangered Species Act (ESA) and other wildlife requirements
Driver 5	Ensuring that MCBCL supports continued military training use of the New River, the NRE, and Onslow Bay while complying with the Clean Water Act
Driver 6	Ensuring the viability of the U.S. Marine Corps New River Air Station as an aviation facility through the elimination of bird and wildlife strike hazards to aircraft while complying with the ESA and other wildlife regulatory requirements

ES-3. Summary of the DCERP Baseline Monitoring and Research Activities

To facilitate an understanding of the ecosystem's state and dynamics at MCBCL, the following five ecosystem modules were established for monitoring, modeling, and research: Aquatic/Estuarine Module, Coastal Wetlands Module, Coastal Barrier Module, Terrestrial Module, and Atmospheric Module. The DCERP baseline monitoring program was designed to gather environmental data and support research projects aimed at addressing MCBCL's ongoing management concerns. Module-specific monitoring and research sites established during Phase II are shown on a map of the Base (**Figure ES-1**).

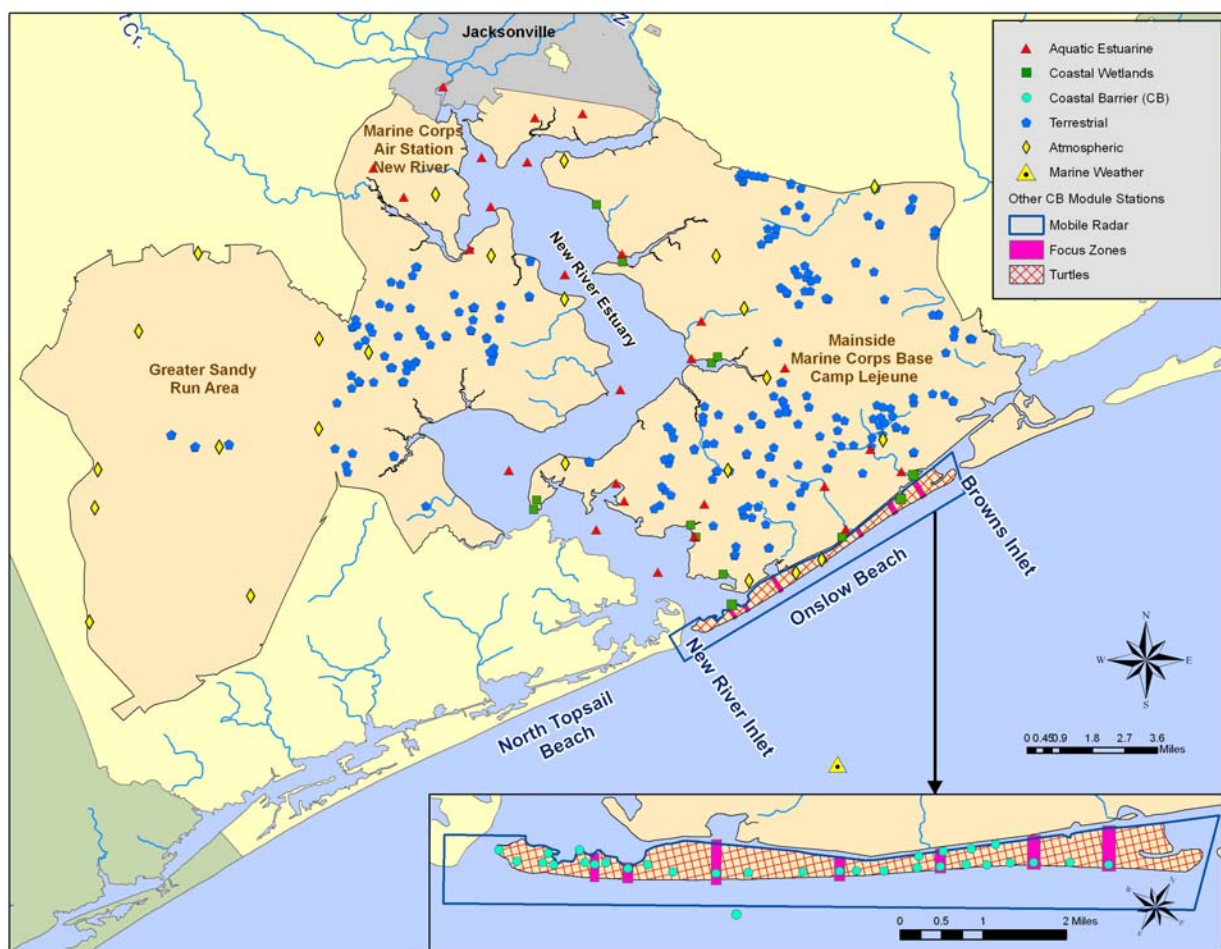


Figure ES-1. Module-specific monitoring and research site locations.

ES-3.1 Baseline Monitoring Program

For the purposes of DCERP, baseline monitoring includes monitoring of basic (fundamental) parameters that support the broader research agendas. Data must be monitored for a sufficient period of time to

determine their information value, and then transitioned in a scaled-down form to MCBCL for monitoring at the end of the DCERP effort. The DCERP monitoring program is described in the *DCERP Baseline Monitoring Plan* and includes the activities listed in **Table ES-2**. All monitoring sites for the five ecosystem modules were established and collected monitoring data during this first year of DCERP implementation.

Table ES-2. Summary of Module-Specific DCERP Baseline Monitoring Program Activities

Modules	Activities
Aquatic/ Estuarine ^a	<u>Hydrodynamics</u> : Stream flow and discharge (New River, New River Estuary [NRE], and creeks) <u>Physical/chemical</u> : Temperature, light, salinity, pH, oxygen, nutrients, (New River, NRE, creeks) <u>Sediment-water column interactions</u> : Total suspended solids and sediment oxygen dynamics (New River, creeks), turbidity (NRE) <u>Biology</u> : Primary productivity, phytoplankton, fluorescence (NRE)
Coastal Wetlands	<u>Land cover and shoreline erosion</u> : Location, elevation <u>Hydrodynamics</u> : Tide gauges (hydroperiod) <u>Chemistry</u> : Nutrients, salinity, hydraulic conductivity (shallow groundwater) <u>Sedimentology</u> : Accretion rates, organic content, particle size
Coastal Barrier	<u>Hydrodynamics</u> : Wave velocity, wave heights/period, currents, shoreline position, morphology <u>Meteorology (ocean)</u> : Air temperature, wind velocity, barometric pressure, humidity, solar radiation <u>Sedimentology</u> : Texture, compaction, composition, sediment volume <u>Biology</u> : Benthic invertebrates, fish, shorebirds/seabirds, dune/shrub/marsh vegetation, sea turtles
Terrestrial	<u>Land cover/land use</u> : Determine changes in land cover/land use (vegetation types, buildings, roads) <u>Biology</u> : Vegetative community assessment, fuel load <u>Soil</u> : Soil bulk density, pH, organic matter content
Atmospheric	<u>Meteorology (air)</u> : Wind speed, wind direction, relative humidity, temperature, solar radiation, precipitation <u>U.S. Environmental Protection Agency criteria pollutants</u> : Ozone and fine and coarse particulate matter (mass)

^a Sediment analysis, chemistry, and biology (including benthic microalgae) of the NRE benthic zone are characterized in Research Project AE-3.

ES-3.2 Research Program

The research program was designed to increase the knowledge base and understanding of MCBCL-relevant ecosystem functioning structure, and system responses to stressors and management actions. The overall research program that is presented in the *DCERP Research Plan* consists of 13 separate research projects, as shown in **Table ES-3**. All planned research projects were started during 2008, with the exception of the two Coastal Barrier Module projects (i.e., Research Projects CB-1 and CB-2) and the field component of Research Project Air-1, which had later start dates and are scheduled to begin in July 2009.

Table ES-3. Summary of the 13 DCERP Research Projects

Research Project Title	Senior Researcher; Project Duration
AE-1: Develop and Deploy Microalgal Indicators as Measures of Water Quality, Harmful Algal Bloom Dynamics, and Ecosystem Condition	Hans Paerli; 7/2007–6/2011
AE-2: Quantifying and Predicting Watershed Inputs of Nutrients, Sediments, and Pathogens	Mike Piehler; 7/2007–6/2011

Research Project Title	Senior Researcher; Project Duration
AE-3: Developing Indicators of Ecosystem Function for Shallow Estuaries: Benthic Functional Responses in the New River Estuary (NRE)	Iris Anderson; 7/2007–6/2011
CW-1: Determine Responses of Marsh Vegetation and Accretion to Relative Surface Elevation	Jim Morris; 7/2007–6/2011
CW-2: Forecast Influence of Natural and Anthropogenic Factors on Estuarine Shoreline Erosion Rates	Mark Fonseca; 9/2007–6/2011
CW-3: Hydraulic Exchange and Nutrient Reactivity in the NRE Wetlands	Craig Tobias; 7/2008–6/2011
CB-1: Short-Term Barrier Evolution Related to Storms and Land Use	Jesse McNinch; 7/2009–6/2011
CB-2: Long-Term Barrier Evolution Related to Variations in Underlying Geology, Land Use, and Inlet Dynamics	Tony Rodriguez; 7/2009–6/2011
CB-3: Understanding the Top-Down and Bottom-Up Drivers of Shorebird Nest Success and Habitat Use in Relation to Beach Management Practices on Marine Corps Base Camp Lejeune	Sarah Karpanty and Jim Fraser; 7/2007–6/2009
T-1: Effects of Different Midstory Restoration Management Options on Terrestrial Ecosystem Structure and Function	Norm Christensen; 1/2008–6/2011
T-2: Effects of Habitat Management for Red-Cockaded Woodpeckers on Bird Communities	Jeff Walters; 1/2008–6/2011
Air-1: Optimization of Prescribed Burning by Considering Mechanical Thinning as a Viable Land Management Option	Karsten Baumann; 7/2008–6/2011
Air-2: Nitrogen Deposition to Terrestrial and Aquatic Ecosystems	Wayne Robarge; 7/2007–6/2011

Note: AE = Aquatic/Estuarine Module; Air = Atmospheric Module; CB = Coastal Barrier Module; CW = Coastal Wetlands Module; T = Terrestrial Module

ES-4. Aquatic/Estuarine Module Summary

Aquatic/Estuarine Module monitoring and research programs have been in place since October 2007. These programs are fulfilling the module's objectives of improving our understanding of the complex physical, chemical, and biotic processes that drive water and habitat quality; differentiating natural and anthropogenic ecosystem stressors (current and future) at local and regional scales; taking account of extreme climatic events, such as hurricanes and droughts; and integrating results with the other DCERP modules. The benefits of the Aquatic/Estuarine Module monitoring and research program include providing information needed to preserve the integrity of the amphibious maneuver areas, including the New River Estuary (NRE) (Military Driver #1), and ensuring continued military training activities while complying with the CWA (Military Driver #5), such as state water quality criteria for chlorophyll *a* and dissolved oxygen (DO) concentrations.

Major accomplishments and benefits to the Base during this past year include the following:

- Results of water quality monitoring at the U.S. Geological Survey stream-gauging station in Jacksonville, NC, indicated that low DO concentrations resulting in hypoxic conditions were detected at mid-depth in the upper estuary during approximately 50% of the year. This suggests that hypoxic conditions originated off-Base in upstream areas of the New River before flowing into the estuarine areas encompassed by MCBCL lands.

- Using diagnostic photopigments, algal blooms were quantified and attributed to individual phytoplankton groups. During a large spring–summer bloom that covered much of the upper estuary, state water quality standards for chlorophyll *a* were exceeded (**Figure ES-2**). The dominant phytoplankton groups causing the bloom are not known to be toxic, but these groups could have been the cause of low DO conditions (hypoxia) recorded in estuarine bottom waters following the blooms. These algal blooms likely occurred because of inputs of nitrogen N from the New River Watershed.

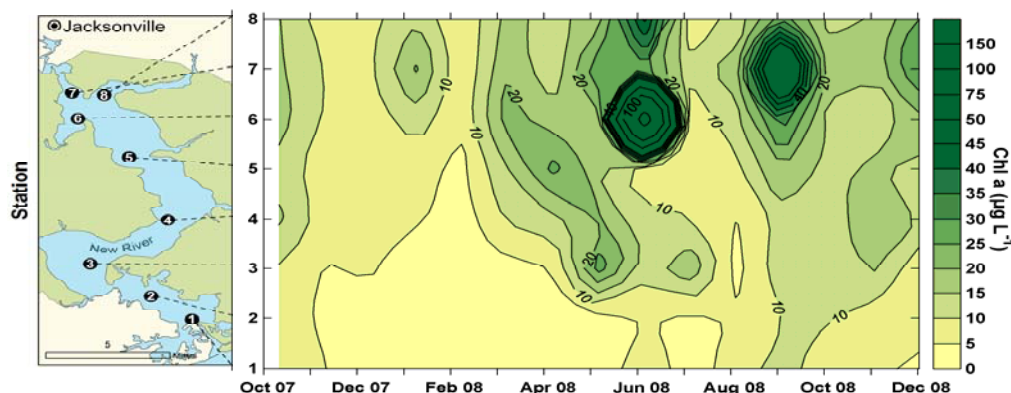


Figure ES-2. Monthly surface chlorophyll *a* showing a large spring–summer bloom covering most of the upper NRE.

- Two distinct peaks in phytoplankton productivity were observed in the NRE: one in spring (April), which appears to reflect the beginning of the spring bloom, and the other in fall (September) that followed the passage of Tropical Storm (TS) Hanna. The zone of maximum productivity appears to be in a region in the estuary between Wilson Bay and Hospital Point, where the NRE widens and residence time increases, thus highlighting an area sensitive to bloom development.
- Assessments of tributary creeks revealed elevated levels of nutrients and suspended materials in creeks with higher levels of human impacts as compared to their paired reference creeks (five pairs totaling 10 stations). Although there were distinctions among creeks with varied land uses (e.g., industrial, forested, urban [non-industrial], residential, military training [bombing range]), the overall concentrations and loads of nutrients and suspended materials from the Base were quite low. At tributary creek research sites (two pairs totaling four stations), the distribution of loading of fecal indicator bacteria, nutrients, and suspended materials in storm- and base-flow was often correlated with human impacts in the watersheds.
- Results of a year-long baseline data collection program to characterize shallow benthic and pelagic habitats throughout the NRE demonstrated moderate eutrophication, nitrogen limitation of pelagic production, and high benthic productivity, suggesting that benthic autotrophy potentially plays an important role in mitigating nutrient enrichment.
- Seasonal in situ mesocosm and laboratory microcosm studies were initiated to determine how benthic and pelagic metabolic properties and nutrient cycling rates vary as a function of ambient nutrient enrichment, light quality, and quantity. Higher rates of denitrification were seen at impacted sites than at less-impacted sites. Benthic processes appeared to mitigate the effects of nutrient enrichment on the NRE.
- The Estuarine Simulation Model (ESM) and hydrodynamic box model for the NRE were designed and calibrated to the estuary for the period 1998–2006 using the long-term water quality monitoring data collected by the University of North Carolina at Wilmington. These models will

produce reasonable predictions of NRE chemical, physical, and biological processes to use in forecasting responses to various MCBCL management actions.

Aquatic/Estuarine Module activities planned for next year include the following:

- Continue to assess human versus climatic impacts on water quality and habitats with an emphasis on impacts from various on-Base and off-Base land uses, military training activities, and storms and droughts to determine the ecological condition and sustainability of the NRE.
- Continue to examine nutrient limitation/enrichment of phytoplankton growth and test diagnostic photopigments and molecular analyses (for harmful algal blooms).
- Perform surface mapping of water quality parameters across shallow-estuarine and tributary waters to understand the influence of watershed inputs from the New River, tributary creeks, and shoreline impacts on shallow-water habitat quality.
- Perform seasonal in situ mesocosm tests in shallow habitats of the NRE and laboratory microcosm experiments to determine how benthic and pelagic metabolisms and nutrient cycling vary as functions of nutrient enrichment and light quality and quantity.
- Determine spatial and temporal patterns in the contributions of the optically active constituents (i.e., particles, phytoplankton, and colored dissolved organic matter) to light attenuation in the NRE, in support of the ESM. These data will also support an analysis of the contribution of MCBCL activities to NRE water quality.
- Continue development of the empirical model and ESM, with particular focus on calibration to DCERP project data, and development of the Watershed Simulation Model with calibration to the Research Project AE-2 annual cycle of watershed loads.

ES-5. Coastal Wetlands Module Summary

The health of the coastal wetlands dictates their ability to serve as a trap for nutrients and sediments, which improves water quality in the NRE. In addition, marshes protect Base infrastructure by serving as a buffer against coastal storms, as well as compensating for sea-level rise. Salt marshes also support the coastal barrier island and are essential to its continued survival. The overall monitoring and research program of the Coastal Wetlands Module is designed to provide quantitative information about the condition and dynamics of coastal marshes at MCBCL and to forecast future changes in the condition of these coastal marshes due to anticipated increases in military training activities and sea-level rise. This module was designed to address two of the MCBCL military drivers: (1) preserve the integrity of the amphibious maneuver areas in the NRE (Military Driver #1) and (2) ensure that MCBCL supports continued military training activities while complying with the CWA (Military Driver #5).

Major accomplishments and benefits to the Base during this past year include the following:

- Eighteen Surface Elevation Tables (SETs) were monitored in the lower NRE and Intracoastal Waterway (ICW) to evaluate changes in marsh surface elevation and sediment erosion/accretion processes.
- Two water-level sensors were installed: one in the lower estuary at Mile Hammock Bay and the other in the middle of the estuary at Wallace Creek (Gottschalk Marina) to provide tidal height data. These data, in combination with marsh elevation distribution, will be used to calculate inundation time (hydroperiod) for coastal wetlands. Tides at Wallace Creek lag tides at Mile Hammock Bay by approximately 3.5 hours.
- The entire NRE shoreline was digitized using 1956 and 2004 aerial photography to provide the baseline for calculating estuarine shoreline erosion rates.

- The ICW shoreline was digitized using 1938, 1956, 1989, and 2004 aerial photographs (**Figure ES-3**). Based on the calculated change in ICW width and shoreline erosion rates for these periods, researchers determined that the width of the ICW has increased by approximately 60 meters over the past 60 years, suggesting that splash point placement along the ICW should be evaluated along with other potential causes to prevent shoreline erosion and maintain barrier island integrity.
- Preliminary results from the analysis of surface elevation change and sediment accretion rates of *Spartina* marshes adjacent to the ICW indicated that surface elevation in all experimental marshes except those at the highest elevation are increasing at a rate greater than the relative sea-level rise projected by several models. However, sediment accretion rates are greater than surface elevation change, indicating significant compaction or decomposition.
- Salt marshes bordering the ICW are nutrient limited. In experimental marsh plots, marsh plant growth dramatically increased following fertilization (300% with addition of nitrogen only and 500% with addition of nitrogen and phosphorus), as did the accretion rate of the marsh surface. These results suggest that marsh fertilization could be a viable management tool to mitigate effects of erosion and sea-level rise.
- The Wave Exposure Model (WEMo) was successfully validated for the NRE. WEMo will be used to develop wave energy forecasts in concert with storm surge scenarios (**Figure ES-4**) needed for development of emergency response scenarios and a comprehensive MCBCL shoreline protection plan.
- A new component for WEMo was developed that provides seafloor shear stress predictions. Data from this component will be used to forecast the resuspension of sediments and the role of resuspension as it influences water quality in the NRE.
- A vessel-wake surveillance system was successfully developed, tested, and deployed to provide the empirical basis for predicting impacts of vessel wakes on NRE shorelines. Using video recordings of vessel movements coupled with simultaneous wave sensor recordings, vessel surveys were conducted at an unregulated speed portion of the ICW through MCBCL lands and near the point where the ICW has eroded to create the shortest distance between the ICW and the ocean.
- Networks of piezometers were installed in coastal wetlands in the lower NRE and ICW to determine water and nutrient fluxes in shallow groundwater of the marshes. Shallow groundwater appears to contribute little excess nutrients into the NRE coastal wetlands. Coastal wetlands are a small source of inorganic nutrients (produced during organic matter decomposition) to the NRE during the relatively dry study period, but a sink for particulate-bound nutrients already in the NRE.



Figure ES-3. Aerial photography was used to determine that the width of the ICW has nearly doubled in 66 years (1938–2004).

Coastal Wetlands Module activities planned for next year include the following:

- Prepare maps (GIS layers) of the distribution and elevation of coastal wetlands (in limited areas).
- Characterize shoreline composition for the entire NRE and compute shoreline erosion and accretion rates as a function of wave energy climate (e.g., wave height, velocity, direction).
- Continue to gather data to parameterize a model of sediment accretion (using Marsh Equilibrium Model 2) that will provide an opportunity to observe the consequences of potential management actions that may be used to mitigate effects of sea-level rise or marsh erosion resulting from landing craft air cushion (LCAC) activity.
- Conduct second year of the marsh organ experiments (Research Project CW-1).
- Collect a second year of SET measurements.
- Continue measuring nutrient flux and composition and freshwater flux in shallow groundwater through piezometer networks deployed at lower NRE and ICW creeks and assess the ability of the coastal marshes to mediate nutrient reactivity and sediment exchange with the NRE.



Figure ES-4. Results from Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model simulating the extent of inundation of MCBCL lands in the lower NRE by a 12-foot tidal surge.

ES-6. Coastal Barrier Module Summary

The coastal barrier island has been identified by MCBCL staff as a critical part of the Base's amphibious assault training program, and thus warrants management strategies that will enable continued training use of the beach while managing it as a sustainable ecosystem. Understanding erosion-rate variability due to various activities will help improve management of the coastal barrier to preserve the integrity of the amphibious maneuver areas, including Onslow Bay (Military Driver #1), and of MCBCL as a combined-arms training Base by ensuring continued viability of its associated training ranges (Military Driver #2). In addition, the Coastal Barrier Module's research and monitoring program will help the Base comply with the ESA (Military Driver #4) by understanding the habitat quality needed to sustain sea turtle and shorebird use of the island.

Major accomplishments and benefits to the Base during this past year include the following:

- The two contrasting morphologies comprising Onslow Island (i.e., high dunes and wide beaches in the north and overwash-dominated areas in the south) appear to be directly related to variations in offshore bathymetry and in the volume of available sediment. These data are crucial for calibrating the shoreline change model to determine future shoreline changes to barrier island morphology.
- The preliminary bar and swash image radar (BASIR) survey clearly defined the dunes, shoreline, and morphology of the shoals around the New River Inlet, even under low wave conditions, suggesting great promise for its intended use in mapping sediment transport pathways during and after storm events. Additionally, this technology may be used to study effects of large-scale MCBCL amphibious training exercises on Onslow Beach.

- Analyses of aerial imagery and preliminary ground penetrating radar surveys indicated that the percentage of overwash comprising Onslow Beach has changed over time, although further work is needed to (1) quantitatively constrain change rates and (2) relate changes in overwash patterns to observed island erosion rates. These data are also crucial for calibrating the short-term and long-term barrier evolution models to determine past and future shoreline change.
- Beach morphology and sediment texture and mineralogy were quantified before and after the USACE dredged the ICW and deposited dredge spoils on north Onslow Beach. These data suggest that sediment is reworked toward the south. This information can be used by the Base, in conjunction with future data, to quantify the impacts and quality of the dredge material deposited on Onslow Beach.
- Abundances of ghost crabs (*Ocypode quadrata*), intertidal invertebrates, and surf fish populations were quantified. Information on these organisms is critical to managing the island for the benefit of ground-nesting birds, sea turtle hatchlings, migrating shorebirds, and surf fish.
- The study of two coastal storm events (TS Hanna and a nor'easter) on beach lithology, beach morphology, and overwash suggested that TS Hanna had little impact on the barrier island due to its short duration and prevailing southeast wave direction, whereas the nor'easter that followed TS Hanna resulted in the northern and southern parts of the barrier island experiencing greater erosion than the center part of the island (**Figure ES-5**).
- Changes in beach surface sediment compaction induced by military vehicles were measured and the location and nature of sediment disturbances specific to different types of military vehicles were recorded. These are the first essential data necessary for determining whether military training activities are contributing to erosion of the training beach.
- Predator camera traps identified a diverse community of both natural and feral predators on Onslow Beach, including bobcat (*Lynx rufus*), raccoon (*Procyon lotor*), opossum (*Didelphis virginiana*), and gray fox (*Urocyon cinereoargenteus*), as well as domestic cats and dogs. Data analyses will provide a more comprehensive understanding of predator dynamics on Onslow Beach and will contribute information to help MCBCL better manage listed species (e.g., shorebirds, sea turtles) and meet requirements of the ESA.
- Extensive documentation of Wilson's plover (*Charadrius wilsonia*) (which is a regional species of concern) demographics and habitat use was obtained and will contribute to the management of this species and other shorebirds of concern (i.e., Piping plover [*Charadrius melodus*], Least tern, [*Sterna antillarum*], and American oystercatcher [*Haematopus palliatus*]).

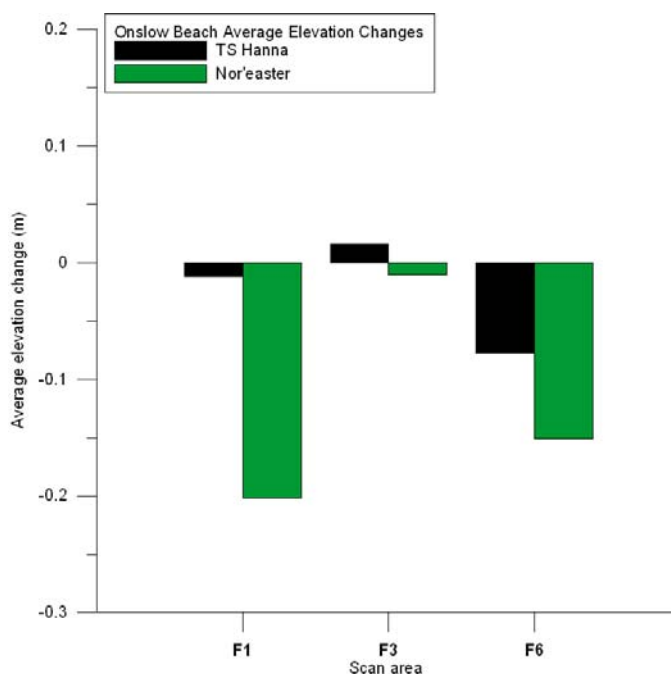


Figure ES-5. Monitoring results suggest that the northern (F1) and southern (F6) parts of the barrier island experienced greater erosion during the nor'easter than the center part (F3) of the island.

- Weekly avian surveys, breeding bird nest searches, and foraging site selection results were made available to MCBCL and were included in MCBCL's reports to the North Carolina Wildlife Resources Commission. This information is currently being used by MCBCL to complete an environmental assessment of potential impacts on listed species from training activities on Onslow Beach.
- MCBCL staff implemented DCERP researcher shorebird management recommendations to erect fencing and post signs around some important foraging and nesting habitat in the southern washover area of Onslow Beach to help reduce impacts to listed species.

Coastal Barrier Module activities planned for next year include the following:

- Validate hydrodynamic models (i.e., Advanced Circulation [ADCIRC] and Simulating Waves Near Shore [SWAN]) that will improve predictions of effects of physical forcings on barrier island geomorphology and sustainability.
- Remap the bathymetry of the surf zone and the topography of 15 beach monitoring sites to assess changes in morphology and sediment distribution along Onslow Beach. These data will help predict how the barrier will respond in the future to storms and sea-level rise.
- Determine sedimentological changes in the three-dimensional structure of the seven beach focus sites over 2 years to evaluate the depth at which sediment is being reworked. These data, along with results from the ground-penetrating radar, will quantify the volume of sediment present on the beach face and explain the along-beach variations in shoreline retreat.
- Quantify aeolian transport of sediments and create images of this transport in several locations behind the dune/vegetated line on the island. Movement of sand, on the beach and behind the dunes, is a fundamental process underlying the quality of the island habitats for fauna, flora, and human activities.
- Continue to quantify the seasonal abundances of benthic invertebrates and ghost crabs, as well as before and after major storm events, and annually estimate surf fish abundances at seven focus sites to address top-down versus bottom-up food-chain dynamics on Onslow Beach.
- Analyze MCBCL's records of off-road recreational vehicle use to identify temporal patterns of beach visitations and potential periods of high vehicle impact to the beach.
- Observe and quantify individual and comprehensive effects of various military vehicles on beach structure during future training exercises.
- Observe and measure sea turtle hatchling survival during their transit across the beach to assist MCBCL management in protecting these listed species.
- Quantify plant species diversity and above-ground structure across Onslow Island at six focus sites over time.
- Describe population dynamics, including predator impacts, nesting, nest success, and fledging success of Wilson's plovers, as well as foraging and nesting habitat availability across the three use zones on Onslow Beach.
- Evaluate the levels and impacts of human use at Onslow Beach on predator abundance, avian distribution and abundance, and Wilson's plover nest success, productivity, and survival.

ES-7. Terrestrial Module Summary

The monitoring and research program of the Terrestrial Module is designed to provide a greater understanding of the Base's management of terrestrial lands and how forest management techniques affect plant and animal communities across MCBCL. One objective of the Terrestrial Module is to

provide baseline information to all DCERP Module Teams on the land-use/land-cover changes that have occurred at MCBCL over the past 20 years and to monitor future changes. Other objectives for this module are to develop and implement protocols for the efficient monitoring of terrestrial ecosystems and to conduct focused studies on existing loblolly pine (*Pinus taeda*) habitat that are being restored to longleaf pine (*Pinus palustris*) habitat by MCBCL natural resources managers to support recovery of the red-cockaded woodpecker (RCW) (*Picoides borealis*). Avian sampling will provide a broader examination of the relationship between RCW management and effects on the composition of the larger bird community. The results from these programs can be applied by MCBCL staff to enhance future training uses of MCBCL ranges and training areas (Military Driver #3) and to ensure that MCBCL supports required military training activities while complying with the ESA (Military Driver #4).

Major accomplishments and benefits to the Base during this past year include the following:

- More than 100 vegetation monitoring plots across the MCBCL were selected, located, and georeferenced. Sites included locations selected by MCBCL staff, Carolina Vegetation Survey sites, and sites identified in collaboration with the Coastal Barrier and Coastal Wetlands modules.
- Sampling for woody vegetation and forest fuels was completed at 30 of 100 vegetation monitoring locations.
- A Landsat Thematic Mapper 5 (TM5) time series was processed for MCBCL and the White Oak Watershed to conduct a Greenness Change Analysis. Greenness represents the intensity of green vegetation at a site as detected in the TM5 image. The Greenness Change Analysis then compares the change in greenness intensity between images taken at different times. Vegetation growth between images is identified by its increase in greenness, such as a cleared field growing to shrubs and eventually a forest. Vegetation removal or thinning is identified by the reduction in greenness, such as forest removal for construction or thinning from forest management practices to improve habitat. The resulting change product from 1984 to 2007 identified all areas where the vegetation density had been altered.
- Between 1984 and 2007, 14,399 hectare (ha) or 25% of MCBCL's total lands (57,824 ha) experienced a significant reduction in greenness density (**Figure ES-6**).
- Of this 25% of land with greenness loss, approximately 3% experienced a severe reduction in greenness density (likely representing the complete removal

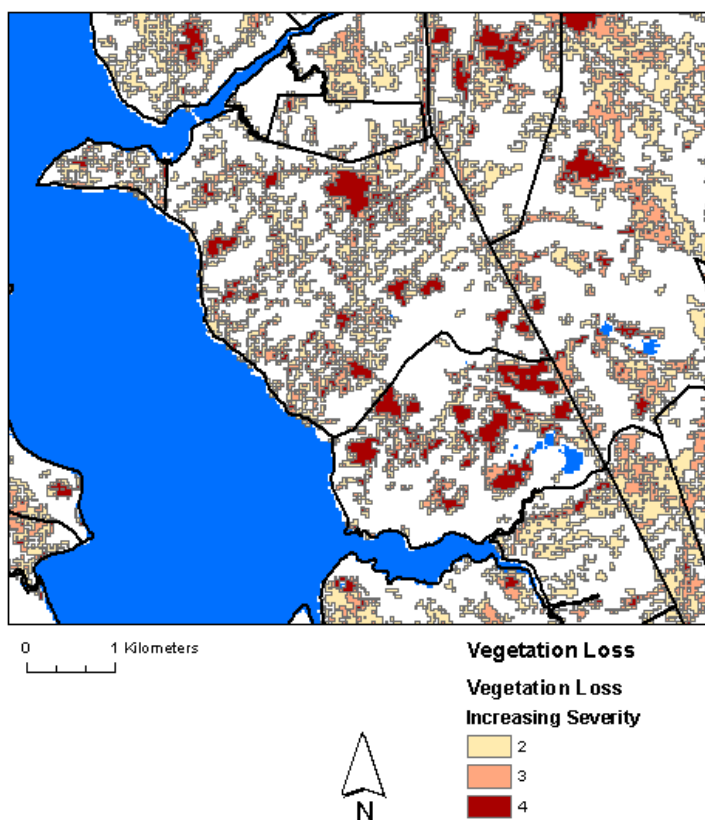


Figure ES-6. Greenness loss intensity (2=small, 3=moderate, 4=severe) for the Hadnot Point and French Creek areas at MCBCL (1984–2007).

of all vegetation for new construction or training areas), 14% experienced small reductions (likely the result of forest management practices to convert dense loblolly pine forest to longleaf pine savannas), and the remaining 8% experienced moderate reductions in vegetation (likely a result of the combination of forest management practices and land-use changes).

- Increased greenness, indicating significant increases in vegetation density, was detected in 2,495 ha, representing 4% of MCBCL lands. The majority of this increase occurred in the Greater Sandy Run Area and likely represents areas of pine plantation growth that were harvested just prior to the 1984 image that re-grew (“greened up”) before the 2007 image.
- Research Project T-1 was redesigned in full collaboration with the MCBCL forestry staff to study the effects of different understory restoration management options on terrestrial ecosystem structure and function across different hydrologic regimes, as well as the impact of forest management for RCW on avian communities in conjunction with Research Project T-2.
- Approximately 150 bird census-point locations were selected to coincide with all Research Project T-1 vegetation research locations, as well as capturing the full range of variation in RCW habitat quality at MCBCL, especially in the longleaf pine habitat.

Terrestrial Module activities planned for next year include the following:

- Acquire and process new Landsat data to update the greenness change analysis to include 2008 and/or 2009 (depends on availability of cloud-free images), process and refine initial hydrologic flow and watershed delineations, and update the reference land-use/land-cover data that were used for the baseline 1984–2007 change detection from the National Land Cover Dataset (NLCD) 2001 product to the NLCD 2006 product (depends upon the release of the NLCD 2006 data for this area).
- Assess the effects of combinations of mechanical and herbicide removal of hardwoods on understory vegetation, insects, and avifauna, and evaluate the influence of manipulation of the forest floor and the addition of native herb seed to the test plots.
- Commence sampling of bird communities on the restoration plots established in Research Project T-1, so that effects of restoration methods on avian communities, as well as RCW foraging habitat quality, can be assessed.

ES-8. Atmospheric Module Summary

The input of nutrients and potential pollutants via atmospheric deposition interacts with most key terrestrial and aquatic ecological processes occurring at MCBCL. The monitoring and research programs of the Atmospheric Module were designed to describe and improve the understanding of critical pollutant transport and advection processes that are subject to complex land-sea-breeze circulation patterns and more regional synoptic forces. This improved understanding will be gained through identification of sources internal and external to MCBCL and their respective range of impacts to ensure Base compliance with the CAA. In addition, the Atmospheric Module is collecting data to estimate the total atmospheric nutrient loading that will assist the Base in meeting CWA goals.

Major accomplishments and benefits to the Base during this past year include the following:

- Three monitoring stations were established at MCBCL, located at an increasing distance away from the shoreline. Meteorological, ozone (O₃), and particulate matter (PM) data have been collected since March 2008.
- Meteorological and air quality data collected from on-Base stations, as well as data from National Weather Service and North Carolina Department of Environment and Natural Resources stations

off-Base have been merged into a data network that allows for analysis of MCBCL air quality in a regional context with a common and consistent time base.

- Initial comparative analysis of MCBCL stations with the regional network of stations using data that spanned July–December 2008 indicate an increasing trend in O_3 and PM concentrations with distance from the ocean. However, none of the current National Ambient Air Quality Standards (NAAQS) were exceeded.
- Based on 6 months of observations from a network of tipping bucket gauges, no readily apparent difference in rainfall amounts across MCBCL was detected. Differences in rainfall amounts among gauges are more a function of localized rainfall intensity within a rain event than physical location.
- Rain events during the fall and winter months result in a relatively uniform pattern in wet deposition across MCBCL as compared to the spring and summer months (**Figure ES-7**); however, spring and summer rainfall events, while highly variable in rain intensity, still have the capacity to impact relatively large areas of MCBCL.

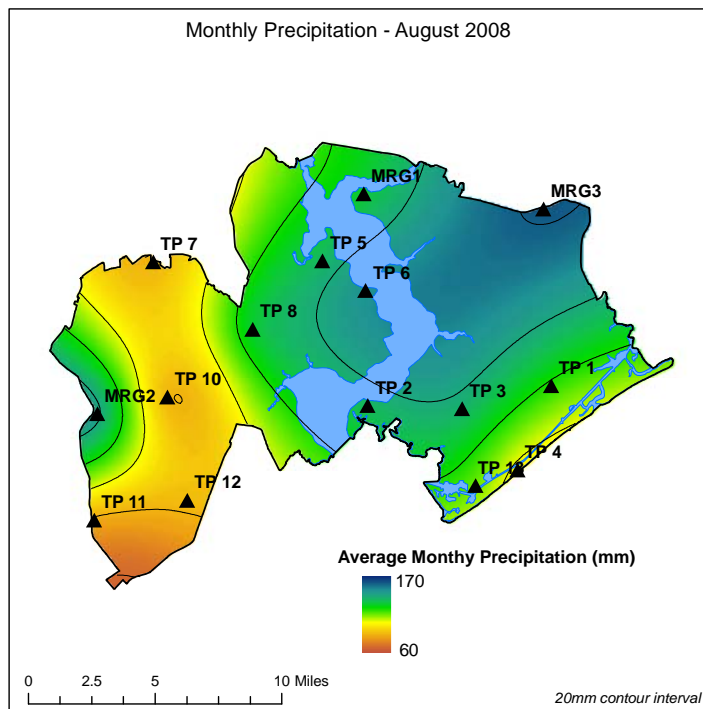


Figure ES-7. Interpolation of monthly precipitation for August 2008 at MCBCL using tipping bucket and manual rain gauges.

Atmospheric Module activities planned for next year include the following:

- Continue to evaluate MCBCL in the context of its regional air quality and prepare monthly and seasonal evaluations of MCBCL air quality against the new seasonal O_3 and daily fine particulate matter ($PM_{2.5}$) NAAQS
- Identify local and regional air quality sensitivities to intensive prescribed burning activities on MCBCL from an evaluation of historic data
- Establish links between air quality indicators and important smoke management parameters such as the Keetch-Byram drought index, boundary layer mixing height, and transport wind speed
- In close cooperation with the Terrestrial Module and MCBCL foresters, implement the Air-1 field study of optimization of prescribed burning by considering mechanical thinning as a viable land management option
- Continue monitoring rainfall events to fully characterize seasonal patterns in rainfall amounts and deploy wet deposition collectors to begin characterizing the chemical composition of rainfall across MCBCL.

ES-9. Data and Information Management System

To support the data management needs of DCERP and the complex and voluminous environmental data to be collected and used for DCERP, it is crucial to make research results, monitoring information, and

other data accessible to the DCERP Team. The DCERP Data and Information Management System (DIMS) is a database-driven Internet system that provides a means to access and manage the DCERP data collections and will provide useful and scientifically sound data and information in a framework that will support ecosystem-based management tools. To accomplish this, the DCERP DIMS consists of the Monitoring and Research Data Information System (MARDIS), the Document Database, public and Collaborative Web sites, and a GIS Mapping Tool for MARDIS.

Major accomplishments and benefits to the Base during this past year include the following:

- The MARDIS data structure and data standards designs were completed and implemented to foster efficient integrated analysis and synthesis of all data collected within and across all ecosystem modules.
- The design and development of MARDIS upload interfaces, database processes, services, and procedures were completed and deployed to the DCERP DIMS servers.
- The MARDIS database and Web site was successfully deployed and made available to the DCERP Team in October 2008.
- Tools to assist the DCERP researchers with transposing their monitoring and research data into the master data templates and into the format necessary for uploading to MARDIS were created. To maximize the time-saving benefits of these tools, the Data Management Team started with data sets that were too labor intensive to manually transform, including the large, consistent, and continuous automated data sets, such as air and water quality data.
- Currently, MARDIS contains more than 4,000,000 records, indicating the potential enormity of the final volume of data to be stored in MARDIS.
- MCBCL GIS data (community feature data sets) are available to the DCERP Team directly from the MARDIS Web site.
- In February 2009, two informational briefing and interactive sessions were held at Camp Lejeune with key MCBCL staff to further discuss how MCBCL envisions using MARDIS data to address Camp Lejeune natural resource management issues. From these collaborative meetings, the Data Management Module Team will be able to recommend future enhancements to the DCERP DIMS that will most directly benefit not only the DCERP researchers, but MCBCL staff as well.

DCERP Data and Information Management System

- Monitoring and Research Data Information System (MARDIS) (password protected)
- Document Database
- Collaborative Web site (password protected)
- Public Web site
- Geographic Information Systems Mapping Tool for MARDIS

DCERP DIMS activities planned for next year include the following:

- Continue to work closely with DCERP researchers to finalize their data sets for uploading so all data sets are available in MARDIS.
- Complete custom tools for predator camera trap and bird survey data, tidal creek monitoring data, dataflow mapping system data, and historical meteorological data. As resources allow, continue developing tools to assist the DCERP researchers with transposing their monitoring and research data into the required MARDIS format for uploading.
- Develop a simple, interactive map viewer for MARDIS.
- Develop a Document Database to be added to MARDIS that will store unstructured data and information such as maps, reports, and photographs.

ES-10. Assessment of Military Training Impacts

In addition to the DCERP research and monitoring activities previously mentioned, SERDP determined that it was important to develop a scientific framework in which to assess the impacts of military training on the various ecosystems of MCBCL at various spatial and temporal scales. To achieve this goal, a review of the scientific literature for the period 1995 to 2007 was conducted on the effects of military training on DoD installations in similar ecological settings or in different ecological settings that employed similar equipment, vehicles, and military training practices to those of MCBCL. Results of the review of acquired reference sources revealed that quantification of military impacts similar to those that might occur at MCBCL based on training practices for troops and vehicles at an estuarine/coastal installation have not been widely reported. Most of the reference studies were conducted at locations (primarily at inland installations) with different soils, vegetation, and climate conditions than occur at MCBCL. Information on methods used to assess specific aspects of military training impacts at the plot, watershed, and regional scales from these studies, therefore, were generally site-specific; however, the methods used by DCERP researchers may be applicable to or adaptable to conditions at MCBCL with slight modifications. The DCERP Team continues to coordinate with SERDP to develop a scientific framework for assessing the impacts of military training that can then be used by researchers to guide experimental treatments for assessing and mitigating the effects of military training to ensure long-term sustainability of the military mission and ecosystem integrity at MCBCL.

ES-11. Summary

The first complete implementation year of DCERP has resulted in significant early findings regarding ecosystem function and structure in areas such as water and air quality, barrier island morphology, and accretion-erosion dynamics in coastal wetlands. Significant findings and progress throughout the year were reported at two Technical Advisory Committee meetings, which included MCBCL and SERDP staff. These meetings provided review and scientific evaluation of each research project's achievements and direction, as well as its relevance to Base management needs. In addition, module team researchers briefed MCBCL staff on monitoring and research efforts during several technical meetings to keep the Base staff informed on DCERP activities and to obtain their feedback to better understand Base management needs. The presentation of findings through various scientific forums and conferences has provided additional peer review and exposed our on-going research efforts to input from the wider scientific community.